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Recycling/Disposal Alternatives for Depleted Uranium Wastes

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All depleted uranium (DU) waste generated during test activities and from unused war reserve is subject to disposal as low-level radioactive waste. At present there is no operational alternative to sending DU wastes to commercial disposal sites for burial. Because of the uncertainties associated with the use of commercial sites in the future, the Air Force is seeking to identify and evaluate feasible recycling/disposal alternatives for

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the disposition of its DU wastes. In this report, potential recycle and disposal options are defined and briefly characterized. For each form of the DU waste, benefits and issues of applicable recycling/disposal alternatives are identified. Based on a comparative evaluation of these options, the most promising mode(s) of disposition are indicated for each type of waste material. The responsibilities and key regulations of government agencies pertaining to the management of low-level radioactive waste are given in an appendix.

PREFACE

This program was conducted by The Analytic Sciences Corporation, 1 Jacob Way, Reading, Massachusetts 01867, under Contract No. F08635-80-C-0199 with the Air Force Armament Laboratory, Armament Division, Eglin Air Force Base, Florida. Mr. Don D. Harrison (DLV) managed the program for the Armament Laboratory. The program was conducted during the period June 1980 to September 1980.

This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

Joe A. Farmer

JOE A. FARMER
Chief, Environics Office

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SUMMARY CONCLUSIONS

This document reports the results of work to identify and characterize options for the recycling and disposal of:

- Depleted uranium (DU) metal from munitions which become unused war reserve
- Expended DU and contaminated sand (test site material) which result from munitions testing at Eglin Air Force Base.

The objective for the work was to provide a basis for future Air Force actions concerning selection and implementation of these options. The scope of work included definition of potential options and their technologies; characterization and extrapolation of regulatory considerations that could affect choice of option(s); definition of technical, regulatory, environmental, institutional, and cost criteria that guide selection of preferred options and use of those criteria to characterize the options; and definition of future work needed to select and implement specific options.

Recycling/disposal options and the significant features of decision criteria for each option are presented. Key points concerning these options and their potential for use can be summarized as follows:

RECYCLING OF UNUSED WAR RESERVE

- Unused war reserve can be recycled to the manufacturing industry, DOE production facilities, or fuel reprocessing plants. There are no apparent technical, regulatory, or environmental constraints on recycling of unused war reserve. Costs should be nominal.

DISPOSAL OF UNUSED WAR RESERVE

- Disposal of unused war reserve would waste a resource with several potential uses in the future. Options for disposal of unused war reserve include burial sites, subseabed emplacement, and decommissioned missile silos. Each option has one or more non-technical constraints (e.g., quantity limitations; regulatory, environmental, or institutional problems) associated with it.

RANKING OF OPTIONS FOR UNUSED WAR RESERVE

The best action for the disposition of unused war reserve is to recycle the DU metal. The alternatives have the following order of descending merit:

- Recycling at DOE/GOCO facility
- Recycling at manufacturing facility
- Recycling at uranium mill
- Disposal at DOE burial site
- Disposal at commercial burial site
- Recycling at nuclear fuel reprocessing plant
- Disposal in decommissioned missile sites
- Disposal at DoD/AF burial site
- Disposal at sea.

RECYCLING OF TEST SITE MATERIAL

- A melting process which is expected to permit recycling of DU waste from the test site is being developed but is not yet proven.

- With appropriate technical and institutional arrangements, this DU waste could be recycled to a uranium mill.

DISPOSAL OF TEST SITE MATERIAL

- Disposal of test site material at commercial low-level waste disposal sites is likely to disappear as a future option because of tighter regulations, closing of existing sites, delays in siting and operating new sites, and limits on quantities and types of wastes accepted at such sites.

- Tailings piles created by mining and milling operations in the uranium industry (western states) and in the phosphate industry (Florida) offer promising options for disposal of test site material. Work concerning technical, regulatory, environmental, and institutional issues would have to precede use of these options.

RANKING OF OPTIONS FOR TEST SITE MATERIAL

The best action for the disposition of test site material is to dispose of this waste at existing, operational facilities. The options have the following order of descending merit:

- Disposal at uranium mill tailings site
- Disposal at phosphate mill tailings site
- Recycling at uranium mill
- Disposal at commercial burial site
- Disposal at DOE burial site
- Recycling at manufacturing facility
- Disposal at DoD/AF burial site.

FUTURE WORK NEEDED

The need for future work to select and implement preferred options can be summarized as follows:

- Use of new technologies and/or procedures which reduce problems associated with disposal of test site material at Eglin Air Force Base and improve the efficiency of use of the site by reducing downtime should be considered.

- There are numerous potential options for either recycling or disposal of both unused war reserve and test site wastes. Implementation of these options, however, will require additional effort to develop specific information concerning the technical and nontechnical factors involved in establishing contractual or interagency agreements that will be needed to use the options.

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SECTION I
INTRODUCTION/BACKGROUND

Depleted uranium (DU) is an excellent material for munitions use because of its high density, pyrophoricity, strength, hardness, ductility, and alloyability with other metals. Since DU is available in excess, it is a relatively inexpensive material. Present uses of DU utilize only a minor fraction of the current stockpile. However, DU is classified as a low-level radioactive material and, as such, must be handled in accordance with Nuclear Regulatory Commission (NRC) guidelines for low-level radioactive waste (Appendix A).

The Air Force currently fields the GAU-8/A 30mm armor penetrating incendiary (API) round which is fitted with a depleted uranium-0.75 percent titanium penetrator. It is anticipated that approximately 20 to 25 million rounds will be procured in the 1980's. A small number of these rounds will be used for test and evaluation at designated Air Force test ranges; the vast majority will be stored for war reserve. The DU material will eventually be subject to disposal as low-level radioactive waste. With the use of DU in conventional munitions (e.g., shape-charge liners, self-forging fragments, and penetrators for other armor-piercing rounds) expected to continue, the volume of DU waste requiring disposal will become greater with time.

At present there is no operational alternative to sending DU from expended munitions at the test sites and from out-of-date war reserve to a commercial disposal site for low-level wastes. Problems of DU disposal are likely to increase in future years. The three states in which commercial sites for disposal of low-level wastes are currently operational (i.e., South Carolina, Nevada, and Washington) continue to restrict the quantities and types of wastes that can be accepted. These actions are partly the result of user deficiencies (e.g., in packaging) which have

caused each state to temporarily close its site on several occasions in recent years.

These State actions are expected ultimately to result in new, regionally-selected disposal sites accompanied by more stringent packaging and waste form requirements. The technologies to prepare DU materials for disposal, and the places and means of disposal, are presently not determined. Moreover, the time at which the new sites will be available is unknown. Two or more decades could pass before new sites are available. Recent experience with attempts to dispose of wastes generated by cleanup of the Three Mile Island accident illustrates the magnitude of this siting problem (Reference 1).

Because of the disposal problems at commercial sites which are anticipated in the coming years, the Air Force is seeking to identify and evaluate potential disposal options as well as feasible recycling alternatives which can provide a direct cost-effective means for the disposition of thousands of tons of DU waste. However, the choice of a recycling/disposal action is not as straightforward as it may initially appear. The Air Force's DU wastes are generated from either testing activities or out-of-date war reserve. Because of the different quantity and impurity content of the DU from each source, it may not be possible, from a technical, regulatory, or economic standpoint, to obtain a recycling/disposal action that is all-encompassing.

SECTION II
OVERVIEW OF RECYCLING/DISPOSAL OPTIONS

A number of alternatives exist for recycling or disposal of the Air Force's DU wastes that are generated during munitions testing and as unused war reserve materiel. In this section, a brief overview of each alternative is presented. These summaries include short-term and long-term recycling/disposal options which may be suitable for either or both types of DU waste material.

1. RECYCLING ALTERNATIVES

a. Manufacturing Industry

(1) Munitions Manufacturing

The principal use of DU today is in the production of penetrators for munitions. The companies involved in the manufacture of these penetrators are listed in Table 1; the major producers are Nuclear Metals, Honeywell, and Aerojet. Currently, Nuclear Metals is the only company which has the full range of processing capabilities (i.e., reduction of UF_4 to machining of final penetrator shape) operational in production.

Several phases are involved in the production process. First, uranium tetrafluoride (UF_4) is reduced to DU metal derby. The derby is melted, alloyed, and cast into billets which are then copper-clad and extruded into long rods. These rods are swaged into preforms and machined into final penetrator shape.

Large amounts of DU wastes are generated during the fabrication process. Solid scrap, such as end pieces, butts, croppings, and defective penetrators, is given an acid (HNO_3) wash to remove surface oxidation and is remelted with virgin material. Assuming no adjustments are made to the melt parameters, the amount of scrap

TABLE 1. COMPANIES PROCESSING DEPLETED URANIUM FOR MUNITIONS PRODUCTION

COMPANY	LOCATION	ACTIVITY
Nuclear Metals, Inc.	Concord, MA	Reduction of UF_4; melt and cast billets; roll and extrude rods; swage into preforms; machine penetrators
Honeywell	Hopkins, MN	Swage into preforms; machine penetrators
Aerojet	Downey, CA	Swage into preforms; machine penetrators
Reactive Metals, Inc.	Astabula, OH	Roll and extrude rods
TNS (subsidiary of Aerojet)	Jonesboro, TN	Reduction of UF_4; melt and cast billets
Eldorado Nuclear Ltd.	Port Hope, Ontario Canada	Reduction of UF_4; melt and cast billets; roll and extrude rods
E-Cubed, Inc.[a]	Los Alamos, NM	Remelting scrap (pilot plant)

[a]No production capability; currently building a pilot plant to demonstrate new process for recycling DU waste.

that can be recycled with virgin material in the melt and not significantly affect properties of the alloy is dependent on impurity specifications for the alloy, quantity and type of contamination in the scrap, and melting process(es) being used. Fine chips and turnings currently are not remelted; these wastes are collected and prepared for disposal at a commercial burial site.

Vacuum induction is the most widely used melting process because of simplicity of equipment, substantial operating experience, and relatively low cost. Virgin material, recycable scrap, and alloying elements are loaded into a melting crucible inside the vacuum chamber of an induction furnace. Material in the crucible

is heated to a liquid state by an induction coil while a vacuum system reduces pressure in the chamber to create an inert atmosphere. As melting occurs, lighter elements in the crucible float up through the molten metal, forming the desired alloyed composition. Induction and/or mechanical mixing and bottom pouring from the crucible into a casting mold are typically done to achieve a more homogeneous composition. The major disadvantage of induction melting is the potential for carbon contamination from the graphite crucible and mold. To reduce this problem, graphite components are coated with metal oxide slurries, melting temperatures are kept as low as possible, holding times are minimized, and atmospheric conditions within the chamber are carefully maintained.

Other melting processes include vacuum arc melting, vacuum skull melting, electroslag refining, and inductoslag melting. These processes all produce alloys with a high purity content, but because of the complex equipment and/or procedures required, use of these methods is reserved for specialized melts. Detailed descriptions of all melting techniques mentioned above are provided in References 2 and 3.

Because of costs and control requirements for disposal of DU wastes, uncertainty associated with the availability of commercial low-level waste disposal sites, and projected increases in the use of DU for defense applications in the future, manufacturers have allocated in-house resources (manpower and funds) for development of new scrap reduction and recycling technology development.

Nuclear Metals, Inc. (Reference 4), currently the largest manufacturer of DU products, recycles solid scrap generated during production back into the melting phase of the fabrication process. The scrap is first pickled in HNO_3 to remove surface contamination and then added directly to the feedstock of virgin material in the melt. Impurities introduced during production (e.g., carbon, hydrogen, and copper) are effectively removed by the HNO_3 wash in conjunction with the induction melting process. Assuming no

adjustments are made to the melt parameters, the ratio of solid scrap to virgin material that is recycled during any given melt is dependent upon the purity requirements of the alloy being produced. For example, Nuclear Metals can recycle up to 100 percent solid scrap from its current DU penetrator production (i.e., XM774, GAU-8/A, and PHALANX) in an induction melt and still achieve the purity requirements of the Air Force's GAU-8/A round. The only preprocessing needed for the scrap is an HNO_3 wash. Nuclear Metals can be expected to recycle scrap penetrators from future GAU-8/A war reserve in this manner, preprocessing only with an HNO_3 bath to remove excess surface impurities. By adjusting the melt parameters, solid scrap can be recycled to meet the purity requirements of any round.

Fine DU chips and turnings which are generated during machining of the penetrator are not now recycled. These chips become coated with a carbonaceous coolant used during machining. Contamination from the coolant hinders purity requirements from being achieved if the chips are recycled directly into the melt. Because of the reactivity of uranium and the large surface-to-volume ratio of the chips, removal of the coolant is difficult and dangerous.

Nuclear Metals has recently been awarded a contract by the Army to evaluate the feasibility of three options for future recycling of DU machining chips:

- Coreduction of oxidized chips with UF_4 and Mg
- Melt chips in slag or molten salt bath using inductoslag melting (this option emulates a pilot process demonstrated at the Bureau of Mines for titanium)
- Convert oxidized chips to UF_4 using H_2F or fluorine gas.

These proposed recycling techniques are in the exploratory R&D stage. It is expected that the most promising method will be operational in 3 to 5 years. In principle, any process for recycling chips can recycle scrap penetrators from unused war reserve.

Honeywell[1] does not have a complete production capability for making DU penetrators; only the swaging and machining phases are done in-house. Extruded rods are obtained from Reactive Metals, Inc. which operates a production facility in Astubula, OH. Eldorado Nuclear Ltd. in Canada provides Reactive Metals with DU billets to make the rods. At present, Honeywell is not involved in any recycle technology development. Large pieces of DU scrap from their production activities are shipped to Nuclear Metals for reprocessing; machine chips are stabilized in cement and shipped to a commercial disposal site for burial. The focus of Honeywell's efforts is to minimize the amount of DU scrap that needs to be recycled.

Currently, Aerojet[2] does not have a full production capability for making DU penetrators in-house. Aerojet converts extruded rods, obtained from Reactive Metals, into final penetrator shape. TNS, a wholly-owned subsidiary of Aerojet, provides Reactive Metals with DU billets from which the rods are formed. However, TNS is in the process of obtaining the equipment to roll and extrude rods. When this equipment becomes operational, Aerojet will have all the processing capabilities necessary to fabricate DU penetrators. Currently solid scrap and chips generated during metalworking and forging/machining phases are converted to a stable oxide (U_3O_8) and shipped to a commercial site for burial. Efforts will continue to emphasize

[1]Telephone Communication, David Broden, Honeywell, Hopkins, MN, July 1980.

[2]Telephone Communication, Harvey Drucker, Aerojet, Downey, CA, July 1980.

scrap reduction. Aerojet/TNS is currently conducting a feasibility study to investigate potential recycling and disposal options for DU scrap and chips.

Eldorado Nuclear Ltd.[1] in Canada recycles DU scrap by the conventional means of remelting solid scrap with virgin feedstock. This company is not willing to discuss its production or development activities.

E-Cubed, Inc. (Reference 5) is developing a continuous melting process for recycling DU scrap. A pilot plant is being built in White Rock, Los Alamos County, New Mexico to demonstrate the process. E-Cubed estimates that a single processing unit can purify 1,000 pounds of scrap per working (8-hour) day; the equipment occupies 100 square feet of floor space, with additional space required for material preparation and handling.

The E-Cubed system is expected to be compatible with present DU alloy production. DU scrap is washed free of external impurities that are picked up during and after machining. It is then vacuum dried and placed into an apparatus of proprietary design which operates at atmospheric pressure. In the apparatus there is a system of patentable design[2]. DU scrap is fed mechanically into the system under nonmechanical forces. As the molten scrap passes through the system, impurities are removed and purified metal is discharged into a billet mold; this is a continuous process. Impurities removed from the DU are discarded periodically. The cleaned billets are returned to the alloying stage of normal production procedures.

[1]Telephone Communication, Lee Winfield, Eldorado Nuclear Ltd., Port Hope, Ontario, Canada, August 1980.

[2]Patent Pending, Process and Apparatus for Recovering and Purifying Uranium Scrap, U.S. Department of Commerce, Patent and Trademark Office, Washington, D.C. Serial Number 133,021, Filed March 22, 1980.

At the production level, the company claims that the cleaned DU billet will contain only a few parts per million of carbon, hydrogen, and nitrogen. If silica is present in the scrap, it will be removed. When large amounts of uranium oxides are present or when the DU is copper-clad, an additional purification step may be required to achieve the desired purity levels.

Uniformity and purity of the recycled DU material are predicted by the inventors of the E-Cubed process to exceed those from usual magnesium reductions. The process is designed specifically to remove impurities and to avoid major sources of nonuniformity in the reductions. Impurities can be removed to reproducible thermodynamic limits, and no problems should occur from gas reactions. Additional features of the E-Cubed process include: no material is processed at high pressure, volume of molten metal processed at any given time is small, and materials are processed in an inert atmosphere.

(2) Commercial Manufacturing

The major current use of DU is for munitions, but there is a small market for DU in the commercial sector. Nonordnance uses include counterweights, ballast, shielding, and special applications machinery. Although the purity requirements for DU metal in nonordnance applications are less stringent than those required for DU used in the production of munitions, the same technology is used to process DU for either application. Currently, nonordnance DU products are manufactured by the same companies which produce penetrators for munitions.

Fast breeder nuclear reactors are a potential future commercial user of significant quantities of DU. These reactors use the DU as a fuel material (the U-238 isotope is converted to fissionable Pu-239). Extensive use of fast breeders in the U.S. is not likely until after the turn of the century. Available and projected inventories of DU from enrichment operations are expected

to be sufficient to supply this and other commercial uses as well as the munition sector.

b. Department of Energy/Government-Owned, Commercially-Operated (DOE/GOCO) Facility

There are a number of DOE/GOCO facilities which process DU metal as part of their activities in support of the Department of Defense's (DoD's) nuclear and conventional weapons programs. Among these are: Feed Materials Production Center, Fernald, OH; Rocky Flats Plant, Golden, CO; and Y-12 Plant, Oak Ridge, TN. These facilities have years of experience processing uranium. Except for specialty melts, vacuum induction is used for melting and alloying the metal.

The Feed Material Production Center[1] has been recycling DU or uranium scrap and machine chips routinely for the last 30 years. Solid DU scrap is cleaned with an acid rinse to remove surface impurities and then is remelted with virgin feedstock. Machining chips are prepared for recycling using a briquetting process. The briquetting process removes the aqueous coolant which coats chips during machining and effectively recovers approximately 85 percent of the DU metal. Chips are washed with a detergent solution and crushed in detergent solution with a swing hammer mill or down running wringer to break up long strings or clumps of metal. The crushed chips are wet centrifuged, pickled in HNO_3, rinsed twice with water, drained, and dried centrifuged in air before being compacted into small briquettes 4 inches in diameter and 2 inches thick. The briquettes are added to any given melt. Approximately 300 pounds of chips can be briquetted at one time. The briquetting equipment is expensive; in the past (and currently), the use of this equipment has been economical only for those facilities processing costly uranium metal.

[1]Telephone Communication, L.M. Levy, National Lead Company of Ohio (Feed Materials Production Center), Fernald, OH, August 1980.

At the Rocky Flats Plant[1], solid DU scrap is typically returned to the melt without preprocessing in an acid bath. A past research and development project involving the Army XM774 antitank round showed that penetrators made with recycled solid DU scrap (up to 100 percent scrap) could not be distinguished chemically from penetrators made with virgin feedstock[2]; in addition, no special preprocessing or adjustment in the melt parameters was required when using XM774 DU scrap. By adjusting the melt parameters, any solid DU scrap can be recycled to the desired purity content. Appropriate adjustments to melt parameters are determined after a few trial castings. Machine chips and turnings are recovered, using a process similar to the briquetting procedure at the Feed Material Production Center, and recycled back into the melt; up to 35 percent of the recovered scrap from chips and turnings is added to virgin material at one time.

At the Y-12 Plant[3], DU waste is currently buried rather than recycled. However, equipment does exist to recycle machine chips, but is not economical to use at the present time. The chip recycling procedure is similar to the briquetting process used at the Feed Material Production Center.

c. Fuel Reprocessing Plant

The reprocessing plant in the nuclear fuel cycle is used to retrieve uranium and plutonium from spent nuclear reactor fuel. At this time the only sites that are operational are run by the Department of Energy (DOE) (Table 2) in support of defense programs.

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[1]Telephone Communication, R.J. Jackson, Rockwell International (Rocky Flats Division), Golden, CO, September 1980.

[2]Unpublished report, R.J. Jackson, Rocky Flats Plant, Golden, CO.

[3]Telephone Communication, Merwyn Sanders, Union Carbide Corporation (Y-12 Plant), Oak Ridge, TN, September 1980.

TABLE 2. REPROCESSING FACILITIES IN U.S.

NAME	LOCATION	OPERATOR	STATUS
Hanford Reservation	Richland, WA	Department of Energy	On Standby
Idaho Chemical Processing Plant	Idaho Falls, ID	Department of Energy	Operational
Savannah River Plant	Aiken, SC	Department of Energy	Operational
Barnwell Nuclear Fuel Plant	Barnwell, SC	Allied-General Nuclear Services	Not Licensed
West Valley	West Valley, NY	Getty Oil	Out of Service

Reprocessing of spent nuclear reactor fuel involves two basic operations: head-end treatment, which removes cladding from the fuel and dissolves it, and chemical extraction, which produces fission products (waste), plutonium, and uranium as three separate output streams. (This process is detailed in References 6, 7, 8, and 9.) Bare DU penetrators could simply be added to the spent fuel fed to the dissolver; the uranium in the penetrators would come out of the extraction operation as part of the uranium product stream.

The material composition of the demilled DU penetrator is compatible with process chemistry. The process might also accept without perturbation the penetrator plus the aluminum windscreen as feed material. More detailed study could evaluate the advantages and disadvantages of recycle procedures in which the munitions are partially demilled and the intact penetrator/windscreen assemblies are used as the feedstock to the reprocessing plant.

d. Uranium Mill

Uranium ores are mined primarily in Texas, Colorado, New Mexico, Wyoming and Utah (Table 3 has a partial listing). Since the concentration of uranium in the ore averages 0.15 percent, a

TABLE 3. A PARTIAL LIST OF U.S. URANIUM MILLING SITES[a]

LOCATION	COMPANY	MAXIMUM CAPACITY (Metric Ton Ore/Day)
Grants, NM	Kerr-McGee Nuclear Corp.	6330
Church Rock, NM	United Nuclear Corp.	2720
Grants, NM	United Nuclear-Homestake Partners	3170
Powder River Basin, WY	Exxon, U.S.A.	2720
Natrona County, WY	Union Carbide Corp.	1090
Gas Hills, WY	Lucky McUranium Corp.	1500
Moab, UT	Atlas Corp.	1000
Cannon City, CO	Cotter Corp.	400
Panna Maria, TX	Chevron	2250
Falls City, TX	Conoco & Pioneer Nuclear, Inc.	2500

[a]Operating in 1978

Source: Reference 11

uranium mill is used to concentrate and purify the metal. There are six basic steps in this uranium milling process: ore preparation, ore leaching, liquid-solid separation, uranium extraction, precipitation, and drying and packaging (References 6 and 10).

Test site waste material could be recycled in a uranium mill by adding it to the ore feedstock used in the milling operations. Unused war reserve, after crushing the bare penetrators, could also be dissolved and added to the leaching step. As is the case for recycling in a fuel reprocessing plant, the DU penetrator material is compatible with process chemistry. Control of the rate at which the DU material is fed into the process might be necessary in order not to alter significantly the isotopic composition of the uranium product.

There are numerous uranium mills that are currently out of service because it is not now economical to extract and process nearby ores. One approach for using this recycling option would be to reopen one of these mills and to dedicate its operation to recycling of DU materials. This approach would eliminate concern about the effect of DU on isotopic compositions.

2. DISPOSAL ALTERNATIVES

a. Uranium Mill Tailings

In the milling phase, during which natural uranium is extracted from mined ore, large volumes of slurry wastes (tailings) are generated. The tailings are composed of sand, slime, and liquid. A typical mill, which processes 1800 metric tons of ore/day, discharges 1800 metric tons/day each of solid and liquid waste. Of the dry solid, U_3O_8 makes up 0.11 percent by weight of the tailings. Uranium accounts for 63 picocuries/ gram of activity in the tailings; however the dominant radionuclide is radium-226 which contributes 450 picocuries/gram. As of 1977, a total of 130 million metric tons of tailings had been generated (Reference 11).

Since the activity of the tailings is higher than allowable for unrestricted access, large earth-dam retention systems, known as tailings ponds, are built. A typical pond will occupy 1 square kilometer and may be 30 meters deep. As the pond dries out, it is covered with 3 meters of earth to reduce the radon gas emissions and to eliminate the need for continuous monitoring and maintenance.

b. Phosphate Tailings

Most of the U.S. phosphate industry is located in central Florida (Table 4). Similar to the processing of uranium

TABLE 4. TYPICAL FLORIDA PHOSPHATE OPERATIONS

COMPANY	LOCATION	ACTIVITY
Agrico Chemical	Payne Creek	Mining, Beneficiation
Agrico Chemical	South Pierce	Milling (Phosphoric and Sulfuric Acids)
Farmland Industries	Bartow	Phosphoric and Sulfuric Acids
Gardinier	Bonny Lake	Mining, Beneficiation
International Minerals and Chemicals	New Wales	Milling (Phosphoric and Sulfuric Acids)
Mobil	Ft. Meade	Mining, Beneficiation
Stauffer	Pinellas	Milling (Elemental Phosphorous)
Source: Reference 13		

ore, mining and milling of phosphate rocks produce large volumes of waste. In addition, the phosphate ores contain marketable quantities of uranium; the U_3O_8 content in these ores averages 0.014 percent (Reference 12).

At the mining facility, phosphate ores go through a beneficiation process which involves washing the ore, screening to remove clays, and concentrating phosphate pebbles by a gravitating flotation process. A typical large mine will produce approximately 3 million metric tons of marketable ore per year (Reference 13). For every metric ton of marketable ore extracted, one metric ton of slime and sand is left. The sand tailings are used in a vast reclamation effort to restore the mined lands. The radioactivity of these tailings (from isotopes of uranium, thorium, and radium) is about 18 picocuries/ gram. The slime, which is retained in ponds 10 meters deep, contains an activity of 134 picocuries/gram and takes up to 20 years to consolidate (Reference 12).

Several companies which produce phosphate products have begun to recover the uranium in the waste generated during milling. The recovery process, similar to that used at the uranium mill, separates uranium from phosphoric acid using a solvent extraction method. In 1979 it was estimated that the phosphate industry would provide 5 percent of the U_3O_8 used in the domestic uranium industry (Reference 11).

c. Commercial Low-Level Waste Disposal Site

The commercial disposal of low-level radioactive waste currently takes place at three sites -- Beatty, Richland, and Barnwell (Table 5); sites at Sheffield and Maxey Flats are closed and are not expected to reopen. At this time medical and educational institutions, commercial industry, nuclear power plants, and DoD dispose of low-level radioactive waste at these facilities.

TABLE 5. COMMERCIAL WASTE BURIAL GROUNDS

SITE LOCATION	OPERATOR	LOW-LEVEL WASTE BURIAL[a] (Cubic Meter)	CAPACITY REMAINING (Cubic Meter)
Beatty, NV	Nuclear Engineering Co.	60,534	257,717
Richland, WA	Nuclear Engineering Co.	16,880	874,398
Barnwell, SC	Chem-Nuclear Systems	146,252	1,427,670

[a]As of January 1, 1978

Source: Reference 15

The three states which regulate these disposal sites have enacted laws requiring stricter packaging, have reduced volume of waste that will be accepted, and have declared that low-level waste disposal should be on a state or regional basis. In particular, the state of South Carolina recently reduced the total volume it will accept to 2,832 cubic meters per month (Reference 15).

A typical low-level waste burial ground covers 70 hectares of flat terrain; of this area, 50 hectares are used for burial. The remaining area is used for buildings, roads, and a 50 meter buffer around the perimeter of the site. Low-level waste is buried in shallow trenches which are 150 meters long, 15 meters wide at the top, 10 meters wide at the bottom and 7.5 meters deep; each trench has a capacity of 8300 cubic meters (Reference 14). The average volume of buried waste is 23,000 cubic meter per hectare. It is estimated that the 113 hectares presently unused at the Beatty, Richland, and Barnwell sites will be filled by the 1990's (Reference 15).

d. DOE Low-Level Waste Disposal Site

There are fourteen active government-owned burial sites operated and regulated by the DOE (Table 6). Major operations include Los Alamos, Idaho, Oak Ridge, Hanford, and Savannah River.

Waste buried at these sites includes low-level and transuranic wastes from research, development, and production activities of DoD, DOE, and other federal agencies at DOE sites. Typically the wastes are buried in relatively shallow trenches which are filled to about one meter from the surface and backfilled with the excavated material. As of October 1, 1978, DOE's inventory of low-level radioactive waste was about 1.7×10^6 cubic meters; this volume is projected to be between 2×10^6 and 7×10^6 cubic meters by the year 2000 (Reference 16).

e. Air Force Disposal Site

(1) Decommissioned Missile Silos

Among the force of land-based strategic missiles, several have been designed for launching from underground silos. These silo structures have very thick concrete walls and floors, extending to 50 to 60 meters below the ground. The launch sites are dispersed over large areas, isolated from population centers.

TABLE 6. DOE LOW-LEVEL WASTE DISPOSAL SITES

SITE	LOCATION
Los Alamos Scientific Laboratory[a]	Los Alamos, NM
Pantex Plant[a]	Amarillo, TX
Sandia Laboratories	Albuquerque, NM
Idaho National Engineering Laboratory[a]	Idaho Falls, ID
Nevada Test Site[a]	Las Vegas, NV
Feed Material Production Center	Fernald, OH
Oak Ridge Gaseous Diffusion Plant	Oak Ridge, TN
Oak Ridge National Laboratory[a]	Oak Ridge, TN
Oak Ridge Y-12 Plant	Oak Ridge, TN
Paducah Gaseous Diffusion Plant	Paducah, KY
Portsmouth Gaseous Diffusion Plant	Piketon, OH
Hanford Site[a]	Richland, WA
Savannah River Plant[a]	Aiken, SC
Lawrence Livermore Laboratory	Livermore, CA

[a]Transuranic waste and low-level waste are buried.

Source: Reference 15

Silo-based missiles currently in operation are Minuteman II and III and Titan II. The Minuteman force, which consists of approximately 1000 missiles, is deployed in Montana, North Dakota, South Dakota, Wyoming, and Missouri. The Titan II force has 54 missiles; these are deployed in Arizona, Arkansas, and Kansas (Reference 17). The silo structures for these missiles are potential repositories for the storage/disposal of DU metal.

At the present time, there are no plans to displace either force. When these systems are deactivated, the launch silos will be decommissioned and become available for alternative uses. (Titan I and Atlas F missiles, also designed for silo-launching, were deactivated in the 1960's; these silos were decommissioned and sold to the general public.)[1]

[1]Telephone Communication, MAJ Clark, Offutt Air Force Base, NB, September 1980

(2) Low-Level Waste Burial Site

Air Force lands, located in unpopulated regions of the U.S. and situated in suitable geologic media, are potential sites for burial of low-level radioactive waste. Since these areas are under control of DoD and the Department of the Air Force, access by the general public and unauthorized military personnel can be restricted.

f. Disposal at Sea

Disposal of waste at sea can be accomplished in two ways: dumping into the ocean and emplacement into ocean sediments. The practice of dumping relies on the large dilution capacity of the ocean to mitigate contaminant concentrations if release occurs. Emplacement into ocean sediments takes advantage of the sediments as a natural barrier between the wastes and the biosphere.

Prior to 1970, the U.S. Atomic Energy Commission licensed the dumping of low-level radioactive wastes into the Atlantic and Pacific Oceans. Dumping consisted of dropping suitably packaged containers of low-level waste from ships. In 1971, ocean dumping was phased out because burial on land appeared to be less expensive and because of concerns over pollution of the seas. Current U.S. law (Marine Protection, Research, and Sanctuaries Act of 1972) prohibits disposal of high-level wastes and requires licensing by the Environmental Protection Agency (EPA) of low-level waste disposal.

Other countries have continued to use the ocean for low-level waste disposal. The Nuclear Energy Agency (associated with the Organization of Economic Cooperation) currently supervises dumping operations for eight European countries. The site presently used is located 1000 kilometers off the European coast (46°N and 17°W) at a depth of about 4.5 kilometers. The Japanese are

initiating in 1980 a program of low-level waste disposal in the Pacific; waste would be dumped in the Northwest Pacific Basin off Japan (Reference 18).

Emplacement of high-level radioactive wastes into the ocean sediments is a disposal option currently under consideration by DOE. This disposal concept relies on the ocean sediments to provide the major barrier to future releases of waste into the ocean. Suitable sites appear to exist in the abyssal hills of the mid-plate, mid-gyre ocean basins. Emplacement might be accomplished by using a penetrometer (a streamlined, ballistic-shaped container) which would fall through the water column and bury the waste within the bottom sediments. The Subseabed Disposal Program has been under way since 1974 to determine the technical, engineering, and environmental feasibility of seabed disposal and evaluate the legal and political acceptability of this action; demonstration facilities are scheduled for completion in 2000 (Reference 19).

SECTION III
REGULATIONS

Various government agencies are responsible for the management of DU waste. The term "waste management" includes the temporary storage, treatment, packaging, and transportation of the waste as well as its disposal (either retrievable or irretrievable). Regulations that affect DU waste management can be found in the Code of Federal Regulations under such headings as radioactive materials, low-level radioactive materials, nuclear materials, hazardous materials, and uranium mill tailings. An overview of current regulatory requirements for DU is given in Appendix A.

The Nuclear Regulatory Commission (NRC) is the lead agency for most radioactive waste regulations. The Department of Transportation (DOT) is the lead agency in setting standards for the packaging and transportation of hazardous materials. The Department of Energy (DOE) has responsibility, independent of NRC and other government agencies, for managing radioactive waste from its own research and development activities which includes defense nuclear waste generated and stored on DOE sites. (However, DOE has no authority over radioactive waste from defense activities at DoD sites.) The future actions of these agencies will most likely influence the regulations of other government agencies.

Over the past decade, DU material, along with other low-level radioactive wastes, has been subjected to more stringent standards and requirements. This action has been, in part, the result of increasing public awareness concerning the dangers from improper transportation and disposal of all hazardous material. There is no reason to believe that these regulations will be relaxed in the future. More likely, as the regulatory agencies gain more experience in administering and enforcing their requirements, the standards will become stricter.

Currently, the health and safety effects from low-level radiation are uncertain, and research is being conducted in an attempt to resolve the issues. With the research evidence to date, it is not possible to establish clear relationships between low levels of ionizing radiation and the health effects. As these relationships become clearer, the results will be reflected in future standards. If the effects from low-level radiation exposure appear to be minimal, a relaxation of certain standards may take place. On the other hand, if the health effects prove to be significant, more stringent regulations can be expected. In the absence of a firm basis for decision, regulatory agencies tend to "err" conservatively. As a result, regulations concerning DU are likely to remain unchanged or become more stringent in the near future.

SECTION IV
ALTERNATIVES FOR UNUSED WAR RESERVE

1. MATERIAL DESCRIPTION

Approximately 20 to 25 million rounds of GAU-8/A ammunition are expected to be stockpiled in the 1980's. If this war reserve is not used by the end of its storage life, more than 6,000 metric tons of DU will require disposition after the rounds are fully demilitarized. (From the use of DU in other conventional munitions, thousands of additional tons of DU waste will also require disposition in the future.)

The GAU-8/A round contains a DU penetrator weighing approximately 300 grams. The penetrator is made from a DU-0.75 percent titanium alloy and contains traces of carbon, iron, nickel, copper, silica, hydrogen, oxygen, and nitrogen impurities. An oxide coating forms on the surface of the penetrator shortly after it has been produced. The extent of degradation to the penetrator over the shelf-life of the round is not documented. However, penetrators that were checked after 5 years showed no signs of deterioration; the penetrators were intact, surface oxidation was not excessive, and no evidence of stress corrosion cracking was observed.[1]

[1]Telephone Communication, Joe Jenus, Eglin Air Force Base, FL, July 1980.

2. RECYCLING OPTIONS

a. Munitions Manufacturing

Depleted uranium from unused war reserve can be recycled effectively by the munitions industry. Up to 100 percent solid DU scrap can be recycled using current process technology and achieve the desired purity requirements for the billet being produced. Depleted uranium penetrators from GAU-8/A war reserve can be recycled into an alloy with similar purity specifications using current technology, preprocessing only with an HNO_3 bath to remove surface impurities. When the DU scrap has a higher impurity content than the material being produced, adjustments in the melt parameters are usually all that is needed to recycle the scrap effectively (Reference 4).

BENEFITS	ISSUES
• No recycling technology development required	• Current technology development is focused on chip recycling; this is in embryonic stage
• In principle, DoD will benefit from future technology development without financing it	- Aeroject (TNS) - studying the problem - Nuclear Metals - lab stage, Army funded
• Cost savings on future munition buys should result	- E-Cubed - lab stage, no government funding

b. Commercial Manufacturing

Manufacturers of DU munitions also process DU for the commercial sector. Nonordnance uses of DU metal typically have less stringent purity specifications than those required for DU munitions. Since the quantity of DU currently used in nonordnance production is small compared to that used for munitions, there is no incentive to recycle ordnance scrap into commercial applications (Reference 4). Although increased commercial applications of DU are anticipated, increased use of DU in munitions is also projected. However if future non-ordnance, large-volume uses of DU emerge (e.g., fast breeder reactors or shipping casks for high-level radioactive waste), the commercial industry is likely to be a promising option for recycling the DU metal in unused war reserve.

BENEFITS

- No recycling technology development necessary
- Less stringent purity requirements for DU than in defense sector
- Same manufacturers process DU for commercial and defense sector
- Potential large-volume commercial uses for DU exist

ISSUES

- Currently, small volume of DU consumed in commercial uses compared to defense applications
- Defense use of DU could increase more rapidly than commercial use in the future

c. DOE/GOCO Facility

DOE/GOCO facilities have had many years of experience processing and recycling DU. Up to 100 percent solid DU scrap can be remelted directly with virgin feedstock; desired purity levels are achieved by simply adjusting the melt parameters. The volume capacity at these facilities is sufficient to accommodate the DU waste from unused war reserve.[1,2]

BENEFITS	ISSUES
• Operational recycling capability exists • Many years experience processing DU	• Interagency agreements needed to recycle DoD wastes at a DOE facility

[1] Telephone Communication, R.J. Jackson, Rockwell International (Rocky Flats Division), Golden, CO, September 1980.

[2] Telephone Communication, L.M. Levy, National Lead Company of Ohio (Feed Materials Production Center), Fernald, OH, August 1980.

d. Uranium Mill

Uranium milling operations can reprocess both DU test material and unused war reserve without significantly affecting process operations or the quality of the uranium produced. All impurities found in either DU waste can be removed as part of the normal milling procedure. The variation in isotopic composition between DU and natural uranium can be offset by large differences in volume and by blending of diverse material compositions before processing (References 6 and 10).

BENEFITS	ISSUES
• Current technology can accommodate test material and unused war reserve at controlled rates	• Mill operators may not want to accept the material; may require financial incentive
• Numerous (commercial) mills available	
• Minimal or no degradation to process technology or quality of product	
• Little or no volume capacity limitations	

e. Fuel Reprocessing Plant

Nuclear reprocessing plants provide a technically feasible option for recycling DU material from unused war reserve into the nuclear fuel cycle. Oxide contamination on the surface of the penetrator and titanium component of the DU alloy (as well as aluminum sheathing on partially demilled ammunition) can be removed easily by the extraction process used to separate uranium and plutonium from spent fuel (References 7, 8, and 9). Since the reprocessing facilities have a large volume capacity, the quantity of DU from unused war reserve does not present a problem.

BENEFITS	ISSUES
• Process chemistry can handle penetrator without perturbations • Little or no volume capacity limitations	• Interagency agreements needed between DoD and DOE

3. DISPOSAL OPTIONS

a. Commercial Low-Level Waste Disposal Site

Although commercial sites are a feasible option for the disposal of DU penetrators from unused war reserve, this option may be impractical because of the large quantity of DU that will require disposition in the future. Disposal regulations are becoming more stringent, existing commercial sites continue to reduce the volume that will be accepted, and closings are anticipated in an effort to force the establishment of more state and regional disposal sites (Reference 15). Although additional commercial disposal sites are anticipated in the future, the number and location of these sites are unresolved, the time at which the new sites will be available is unknown, and the extent of changing regulations (and the subsequent effect on disposal practices and costs) is uncertain.

BENEFITS

- Existing 3 sites are well-established and operational
- Procedures and requirements for disposal are well-known
- Replacement or additional sites are expected on state or regional basis in future

ISSUES

- Current and projected status of commercial disposal sites:
  - volume reduction
  - significant increase in burial costs
  - threatened closings
  - restrictions on out-of-state deliveries
  - tighter packaging requirements
- Uncertainty regarding time and location of future sites and impact of changing regulations on disposal practices and costs

b. DOE Low-Level Waste Disposal Site

The Department of Energy currently maintains several sites for disposing low-level radioactive wastes generated from their defense and non-defense programs. Depleted uranium material from both unused war reserve and testing activities is compatible with the wastes buried at these sites. However remaining burial capacity is declining, and current DOE policy limits the disposal at DOE sites to wastes generated by activities at those sites (Reference 15).

BENEFITS	ISSUES
• Numerous active sites	• Interagency agreements needed to dispose of DoD wastes at a DOE site or low-level DoD wastes at a DOE site for nuclear DoD wastes
• Costs should be ≤ costs at commercial disposal site	• Remaining burial capacity at current DOE sites may not be sufficient to accommodate waste disposal from non-DOE sources
• Fewer nontechnical issues associated with these sites than commercial sites	• Current policy restricts burial to DOE-generated wastes

c. Decommissioned Missile Silos

Decommissioned missile silos are potential repositories for thousands of pounds of DU waste from unused war reserve. The silo structures, extending many meters into the ground, have thick concrete walls and floor. Although water intrusion is a problem at certain silo launch sites, there are silos situated in geologic media above the water table. The anticipated availability of the silos is the year 2000[1]; this time frame is compatible with demilitarization/disposal projections for current DU munitions.

BENEFITS	ISSUES
• Makes use of obsolete facilities	• Not all silos are impervious to groundwater
• Provides "ready-made" disposal site	- some action may be needed to seal structures
- silos are contained structures	- data gathering and evaluation effort is needed for all silos under consideration
- silos are already on Air Force land and in Air Force control	• May require Air Force to establish NRC-licenced disposal site
- silos are located away from populated areas	• Use of silo as disposal site may conflict with present and future activities in the area
• Frees Air Force from commercial disposal site issues	• Agreements within the Air Force are needed to realize this alternative
• Overall costs should be $\leq$ costs of commercial disposal site, although transportation costs would increase	

[1]Telephone communication, MAJ Clark, Offutt Air Force Base, NB, September 1980.

d. DoD/AF Low-Level Waste Disposal Site

Establishing a low-level radioactive waste burial site on DoD/AF land provides an "in-house" alternative for the disposal of DU wastes from both test material and unused war reserve. Such a step was taken by DoD for disposing of low-level radioactive waste from Defense Nuclear Agency activities. Although assuming responsibility for maintaining a disposal site would alleviate immediate problems/restrictions and future uncertainties associated with burial at commercial sites, this action may prove less than ideal in the long run because of the costs and administration required for the continued care of a waste site.

BENEFITS	ISSUES
• Accommodate test material and unused war reserve	• Air Force must establish NRC-licensed disposal site
• Located on Air Force land and in Air Force control	• Effort and expense involved in locating and preparing a suitable site
• Frees Air Force from politics of commercial low-level waste disposal issues	• Loss of land for future alternative uses
• Utilizes a remote site not in use	• Continual monitoring, etc. required to maintain site
• Solves the Air Force's short-term and long-term DU disposal problems	

e. Disposal at Sea

"Dumping" of radioactive wastes onto the ocean floor is currently prohibited by the U.S. (Reference 18); this prohibitation is likely to continue to be national policy. Subseabed disposal of high-level radioactive wastes is currently being evaluated by DOE. If this mode of disposal proves to be acceptable for the high-level wastes, technically it will be acceptable for low-level DU wastes. Evaluation and implementation of this disposal mode is expected by about the year 2000 (Reference 19).

BENEFITS	ISSUES
• Avoids land-based disposal siting problems	• May spark an unwanted public (thus political) controversy at home and abroad
• Easy to implement	• Outright ocean dumping is no longer allowed in U.S. without EPA permit
• Current practices by European nations provide precedents	• Modifications to Law of the Sea may be necessary (currently being considered for subseabed disposal of high-level wastes)
	• Precludes retrieval of DU in the future and denies a resource (e.g., fast breeder reactor fuel)

SECTION V
ALTERNATIVES FOR TEST SITE MATERIAL

1. MATERIAL DESCRIPTION

Approximately 100,000 to 150,000 rounds/year of GAU-8/A API ammunition are scheduled to be test fired; this amounts to 30 to 45 metric tons/year of expended DU. These rounds are fired into a partially-filled, contained sand pit about 40 by 20 by 20 feet in size. As a result of continuous testing, sand in the central area of the container becomes pulverized. This powdery substance clogs the filtering system of the test facility, requiring the sand to be replaced periodically. Current cleaning practice requires that the sand be changed every 6 months or after 20,000 rounds have been fired.

The sand butt contains about 350 yards of sand, expended DU, and aluminum fragments when cleaning is required. This quantity of material fills about 1100 55-gallon drums for disposal. Expended DU in the sand butt ranges in size from intact penetrators to submicron particles. Some of the DU is converted to uranium oxides upon impact; these oxides form amalgamates with the silica and metal impurities present in the container.

In an attempt to reduce the quantity of material requiring disposal, only the core area of the container is replaced and no sifting to separate the DU and sand is done. Range personnel estimate the DU content in the core to be about 70 to 75 percent and the DU in the noncore area to be about 1 to 4 percent. This limited cleaning practice significantly reduces the quantity requiring disposal. Periodically the entire contents of the sand butt will be changed.[1]

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[1]Telephone communication, Richard Crews, Eglin Air Force Base, FL, August 1980.

2. RECYCLING OPTIONS

a. Uranium Mill

The uranium milling operation can process both DU test material and unused war reserve without significantly affecting the quality of the uranium ore being processed. All impurities found in either DU waste form can be removed as part of the normal milling procedure. The variation in isotopic composition between DU wastes and uranium ore can be offset by large differences in volume and by blending of diverse material compositions before processing (References 6 and 10).

BENEFITS	ISSUES
• Current technology can accommodate test material and unused war reserve at controlled rates	• Mill operators may be unwilling to accept the material; financial incentive may be required
• Numerous (commercial) mills available	
• Minimal or no degradation to process technology or quality of product	
• Little or no volume capacity limitations	

b. Manufacturing Industry

Currently, none of the DOE/GOCO facilities processing DU nor the companies involved in DU munitions manufacturing have the capability to remove the silica contamination present in DU waste material generated at the test site. Silica contamination is not an industry concern since high concentrations of this impurity are not present in the DU processed by these facilities. Technology development within industry is focusing on the recycling of machine chips.

One company, E-Cubed, is developing a continuous melting process for recycling DU scrap which the company claims can remove silica contamination (Reference 5). However, the E-Cubed process is not a demonstrated capability; a pilot plant is being constructed for this purpose. If industry does not adopt this technology when it is demonstrated, the Air Force would have to operate or finance a facility employing the E-Cubed system to use this process for recycling DU waste from the test site.

BENEFITS	ISSUES
• Potentially capable of recycling test material and unused war reserve	• E-Cubed process currently not demonstrated
• Procedure expected compatible existing process technology	• E-Cubed has no production capability at present time
• Recovery [illegible]ts estimated to be < combined costs of waste disposal and new metal preparation	• May require the Air Force to get involved in the recycling business

3. DISPOSAL OPTIONS

a. Commercial Low-Level Waste Disposal Site

Although test site material is currently buried at a commercial disposal site, the future availability of this option is uncertain. Disposal regulations are becoming more stringent, costs are rising, and quantities accepted by existing sites are being restricted (Reference 15). Additional commercial sites are expected for the future (ca. 1990-2000), but the circumstances surrounding the existence and use of these sites are currently not established and probably will not be resolved for about 10 years.

BENEFITS	ISSUES
• Existing 3 sites are well-established and operational • Procedures and requirements for disposal are well-known • Replacement or additional sites are expected on state or regional basis in future	• Current and projected status of commercial disposal sites: - volume reduction - significant increase in burial osts - threatened closings - restrictions on out-of-state deliveries - tighter packaging requirements • Uncertainty regarding time and location of future sites and impact of changing regulations on disposal practices and costs

b. DOE Low-Level Waste Disposal Site

The Department of Energy currently maintains several sites for disposing low-level radioactive wastes generated from its defense and nondefense programs. Depleted uranium material from both unused war reserve and testing activities is compatible with the low-level wastes buried at these sites. However remaining burial capacity is declining, and current DOE policy limits the disposal at DOE sites to wastes generated by activities at those sites (Reference 15).

BENEFITS	ISSUES
• Numerous active sites • Costs should be ≤ costs at commercial disposal site • Fewer non-technical issues associated with these sites than commercial sites	• Interagency agreements needed to dispose of DoD wastes at a DOE site or low-level DoD wastes at a DOE site for for nuclear DoD wastes • Remaining burial capacity at current DOE sites may not be sufficient to accomwaste waste disposal from non-DOE sources • Current policy restricts burial to DOE-generated wastes

c. DoD/AF Low-Level Waste Disposal Site

Establishing a low-level radioactive waste burial site on DoD/AF land provides an "in-house" alternative for the disposal of DU wastes from both test material and unused war reserve. Such a step was taken by DoD for disposing of low-level radioactive waste from Defense Nuclear Agency activities. Although assuming responsibility for maintaining a disposal site would alleviate immediate problems/restrictions and future uncertainties associated with burial at commercial sites, this action may prove costly in the long run for the continued care of a waste site.

BENEFITS	ISSUES
• Accommodate test material and unused war reserve	• Air Force must establish NRC-licensed disposal site
• Located on Air Force land and in Air Force control	• Effort and expense involved in locating and preparing a suitable site
• Frees Air Force from politics of commercial low-level waste disposal controversy	• Loss of land for future alternative uses
• Utilizes a remote site not in use	• Continual monitoring, etc. required to maintain site
• Solves the Air Force's short-term and long-term DU disposal problems	

d. Uranium Mill Tailings

Although the concentration of uranium in test site waste is higher than the concentration in uranium mill tailings, the material composition of these two wastes is similar. Numerous tailings piles of large volume currently exist in which the disposal of test site waste could be accommodated (Reference 11). However, regulations for tailings piles are becoming more stringent (Reference 20), which may place some restrictions on the use of these piles for disposing test site waste.

BENEFITS	ISSUES
• Numerous tailings piles • Existing tailings piles are significantly larger than potential volume from testing • Costs should be ≤ costs at commercial disposal site • Require no preprocessing of test material beforehand • Land used for tailings piles is not slated for reclamation (at this time)	• Concentration of DU in test material may have to be reduced before disposing to meet density and activity requirements for piles • Mill operators may be unwilling to accept the material; financial incentive may be required • Tailings piles are classified as by-product material which requires NRC license • State and federal control is increasing

e. Phosphate Tailings

Large phosphate tailings piles currently exist in Florida. The inert materials in the phosphate tailings and test site wastes are similar, although the uranium concentration in phosphate tailings is much smaller than the uranium concentration in test material. However, the large volume of tailings compared to that of test material permits compatibility in uranium concentration when these two wastes are mixed. At present, no radioactivity limits have been designated, nor licensing required, for the phosphate tailngs piles (References 12 and 13).

BENEFITS	ISSUES
• Primary sites located in Florida, thereby minimizing transportation costs • No NRC or EPA licensing required for piles at this time	• Future licensing of piles is expected -- may be prohibitive for DU • Land used for phosphate piles is typically reclaimed at future date -- DU may prohibit this • Phosphate industry is investigating economical means to extract uranium from phosphate wastes • Concentration of DU in test material will have to be reduced to be compatible with uranium concentration in phosphate waste

SECTION VI
COMPARATIVE EVALUATION OF ALTERNATIVES

1. DECISION/EVALUATION CRITERIA

Numerous options for recycling or disposal of unused war reserve and test site material have been identified. Consequently, criteria are needed to guide selection of the preferred mode(s) of disposition of each type of material.

Issues to be addressed by the criteria include:

- Will the recycling or disposal technology be available when needed?
- Is special action needed to make the unused war reserve and test site material compatible with the recycling or disposal technology?
- Are there limits on the rate at which unused war reserve and test site material can be accepted by the technology?
- Will anticipated changes in regulations, if any, affect the availability of the option?
- Will use of the option produce significant adverse environmental impacts?
- Are there, or might there be, significant institutional constraints affecting use of the option?
- Is the option cost-effective?

All of these issues are pertinent to disposition of both unused war reserve and test site material, but they apply differently to the various options. In Table 7, these issues are presented as decision criteria and the significant features of each criterion are indicated for each recycling and disposal option for unused war reserve. Table 8 presents the same type of information for each potential recycling and disposal option for test site material.

TABLE 7. OPTION-CRITERIA RELATIONSHIPS FOR DISPOSITION OF UNUSED WAR RESERVE

OPTION \ CRITERIA	TIMELY AVAILABILITY OF TECHNOLOGY	NEED FOR PREPARATORY ACTION	LIMITS ON RATE OF DISPOSITION	EFFECT OF EVOLVING REGULATION	POTENTIAL FOR ENVIRONMENTAL ISSUES	POTENTIAL FOR INSTITUTIONAL CONSTRAINTS	COST EFFECTIVENESS
Recycle	ALL TECHNOLOGIES CURRENTLY EXIST	DEMIL TO ISOLATE PENETRATOR		NO SIGNIFICANT EFFECTS EXPECTED	NO SIGNIFICANT ISSUES EXPECTED	INTERAGENCY AGREEMENTS OR CONTRACTS NEEDED	
DOE/GOCO Facility			None				Low Cost
Munitions Manufacturing			None				
Commercial Manufacturing			None				Typical Commercial Costs
Uranium Mill			Isotopic Composition of Product				
Fuel Reprocessing Plant							Low Cost
Disposal		DEMIL TO REMOVE PROPELLANT AND/OR SHEATHING					COSTS EXPECTED TO BE SIMILAR FOR ALL OPTIONS
Commercial Site	New Sites Needed; Not Available Until 1990's		Rate of Capacity Increase	Could Eliminate Option	Will Probably Delay Development	States Could Foreclose Option	
DOE Site	Exist Now		Availability of Capacity	None	None	Interagency Agreement Needed	
Missile Silos	Need Phase-Out of Current Use		Rate of Phase-Out of Current Use	Could Eliminate Option	Could Delay Use	Public, State, and Regulatory Issues	
DoD/AF Site	Would Need to be Sited and Developed		Availability of Capacity	None	Could Delay Development	None	
Subseabed	Earliest Available is 1990's		None	Evolution to Permit Option is Needed	Could Prohibit Use	None if Option is Accepted for High-Level Wastes	

TABLE 8. OPTION-CRITERIA RELATIONSHIPS FOR DISPOSITION OF TEST SITE MATERIAL

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CRITERIA / OPTIONS	TIMELY AVAILABILITY OF TECHNOLOGY	NEED FOR PREPARATORY ACTION	LIMITS ON RATE OF DISPOSITION	EFFECT OF EVOLVING REGULATION	POTENTIAL FOR ENVIRONMENTAL ISSUES	POTENTIAL FOR INSTITUTIONAL CONSTRAINTS	COST EFFECTIVENESS
Recycle							
Manufacturing Industry	Only Process Concept Now In Early Development		Process Capacity	NO SIGNIFICANT EFFECTS EXPECTED	NO SIGNIFICANT ISSUES EXPECTED	CONTRACTS NEEDED	Unknown At Present
Uranium Mill	Exists Now		None				Low Cost
Disposal							
Commercial Site	New Sites Needed; Not Available Until 1990's	COMPLY WITH TEST SITE SAFETY REQUIREMENTS	Site Capacity	Could Eliminate Option	Will Probably Delay Development	States Could Foreclose Option	
DOE Site	Exist Now	PACKAGE TO MEET TRANSPORT REQUIREMENTS	Site Capacity	None	None	Interagency Agreement Needed	COSTS EXPECTED TO BE SIMILAR FOR ALL OPTIONS
DoD/AF Site	Would Need To Be Sited And Developed		Availability Of Capacity	None	Could Delay Development	None	
Uranium Mill Tailings	Exist Now		None	Uncertain; May Restrict Use	Issues Expected, But Primary Use Factors Govern	None After NEPA Compliance; Contracts May Be Needed	
Phosphate Tailings	Exist Now		None				

2. COMPARATIVE EVALUATION OF OPTIONS

a. Options for Disposition of Unused War Reserve

Two major conclusions are evident from the information presented in Table 7.

- There are several possible options for recycling of unused war reserve.
- There are no attractive options for disposal of this material.

Technologies currently exist for all of the recycling options; none of these options is significantly affected by existing or potential regulatory and environmental issues; and all can be implemented at reasonable cost.

No limitations on the rate of recycling of demilled unused war reserve to DOE/GOCO facilities, the munition industry, or commercial industry are foreseen. There may be limitations on the rate of recycling to uranium milling operations or to a fuel reprocessing plant because of the impact of a large quantity of DU material on the isotopic composition of the products from these operations. In practice, however, these limitations can be minimized if the rate at which the munitions are withdrawn from service is not too rapid.

Disposal of unused war reserve can be accomplished if necessary, but such action is wasteful of a valuable resource. Current and projected information indicates that burial at a DOE site would be the best overall choice of the disposal options since existing or potential environmental, regulatory, and cost issues do not appear to be a problem. However, careful interagency planning would be needed to implement this option.

b. Options for Disposition of Test Site Material

Table 8 shows that there are several potential options for disposition of test site material. Both recycling options are attractive but limited. With appropriate contractual arrangements, the test site material can be blended into existing uranium milling operations with little or no impact. If the E-Cubed process proves to be successful, this DU waste can be recycled to manufacturing industry.

Disposal at commercial low-level waste sites faces an uncertain future. This option, in principle, will remain available indefinitely but anticipated changes in regulations, costs, and site capacities may make the option impractical. Given the uncertain nature of this option, the Air Force should anticipate the use of a different disposal mode in the future.

Disposal of all waste in uranium or phosphate mill tailings piles is one of the most attractive options for test site material. Although regulation of tailing piles is becoming more stringent, the material composition of the tailings and the tests ite material (with large DU fragments removed) is so similar that the test site material can be disposed of in the tailings piles without affecting the existing material characteristics.

If site capacity is sufficient, disposal of test site material in a DOE low-level waste site is also possible. These sites are subject to controls similar to NRC regulations. Appropriate interagency agreements with DOE would be needed to use this option.

3. ADDITIONAL INFORMATION AND STUDY REQUIREMENTS

The characterization and assessment of DU recycling/ disposal options in this study provide baseline information from which the most promising alternatives for the management of each

DU waste form can be identified. Rejection of some options will occur at this stage, e.g. because regulations cannot be met or because supportive process technology is lacking. Additional data gathering and analysis should focus on those recycle/disposal options selected for more detailed evaluation.

For each option retained for further consideration, more detailed study should emphasize the specific information needed to satisfy decision-making criteria. Detailed characterizations, though often necessary, can become a "laundry list" of facts from which no practical decision can be made. In Tables 9 and 10, some additional information and study requirements are suggested for the recycling and disposal options discussed in Sections II, IV, and V. In addition, for each alternative selected for more detailed study, a complete cost-benefit evaluation highlighting key direct and indirect considerations should be performed as well as a thorough review of current applicable regulations.

For test site material there is a unique option not explicitly considered in this work: change the waste form, i.e., separate the DU from the sand so that the DU can be disposed of or recycled as a much smaller volume of material. Future work in this direction would involve devising an effective separation technology and evaluating the tradeoffs associated with its use.

TABLE 9. NEEDS FOR ADDITIONAL DATA ON RECYCLING OPTIONS

OPTION	DATA NEEDS AND STUDY REQUIREMENTS
Munitions Manufacturing	• Detail how the AF could make use of recycling within munitions industry. Evaluate the cost impact on future production buys. • Obtain detailed information on the E-Cubed recycling process. Evaluate the viability of its being implemented.
Commercial Manufacturing	• Identify future application of DU for ordnance and non-ordnance uses and the projected volume requirements of each.
DOE/GOCO Facility	• What institutional arrangements are required?
Fuel Reprocessing Plant	• What institutional arrangements are required?
Uranium Mill	• Determine criteria required by mill operators to accept DU waste, e.g., minimum volume, form of material, payments, etc. • What contract requirements are necessary?

TABLE 10. NEEDS FOR ADDITIONAL DATA ON DISPOSAL OPTIONS

OPTION	DATA NEEDS AND STUDY REQUIREMENTS
Uranium Mill Tailings	• Determine DU concentration limits for disposal in a tailings pile. • Determine criteria required by mill operators to accept DU waste. • Ascertain how restrictive future regulation is expected to be.
Phosphate Tailings	• How receptive is the phosphate industry? • How restrictive is future regulation expected to be? • At what stage is development technology for extraction of U from phosphate ores? Determine the applicability for DU recycling.
Commercial Site	• Where are future sites expected to be? When? Capacity? Restrictions?
DOE Site	• What institutional arrangements are required?
Decommissioned Silos	• Prepare physical description of the silos. • Obtain geologic and environmental description of launch sites. • Evaluate quantitatively the potential impact to man and environment should water intrusion occur.
DoD/AF Site	• Prepare Environmental Impact Assessment at least; Environmental Impact Statement at most. • Determine pertinent NRC and DoD requirements and the logistics in completing this mission.
Subseabed Disposal	• Insure understanding of EPA, NRC, and DOE responsibilities and future direction that is expected. • Obtain quantitative analysis of potential impact to environment and man from releases of waste emplaced in sediments; risk assessments over time.

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APPENDIX A
REGULATIONS PERTAINING TO DEPLETED URANIUM

The regulatory policies of the Government are carried out by many Federal agencies. Eleven executive branch departments exist, each containing numerous offices and divisions, and each having specific legislative mandates and legal jurisdiction. In addition, special government commissions and agencies at both the Federal and State levels may also be empowered to implement national policies. As a result, there are often many agencies that implement and enforce regulations in a given area.

The regulation of depleted uranium (DU) falls within the authority of several government agencies. The jurisdiction of these agencies and pertinent regulations currently affecting the management and disposal of DU waste are summarized in this appendix.

1. NUCLEAR REGULATORY COMMISSION

The Nuclear Regulatory Commission (NRC) has lead responsibility for regulating DU. NRC's authority is derived principally from the authority of the former Atomic Energy Commission (AEC) to regulate human exposure to radiation. All regulatory functions of the AEC were transferred to NRC by the Energy Reorganization Act of 1974, which created the NRC. Under this act, NRC has broad authority to license and regulate the use and distribution of DU and to establish minimum criteria for the issuance of licenses. In addition, NRC has broad authority to regulate licensees. These authorities have been implemented by NRC through regulations set forth in Title 10 of the Code of Federal Regulations (CFR), Parts 20, 40, 51, 60, 71, and 150 (Table A-1) (Reference A-1).

Part 20 regulates level of radiation exposure that can be received by individuals resulting from possession, use, and transfer of licensed material by any licensee. This includes radiation

TABLE A-1. CURRENT REGULATIONS OF THE NRC
TITLE 10 - CODE OF FEDERAL REGULATIONS

10 CFR 20	-	Standards for Protection Against Radiation
10 CFR 40	-	Domestic Licensing of Source Material
10 CFR 51	-	Licensing and Regulatory Policy and Procedures for Environmental Protection
10 CFR 61	-	Management and Disposal of Low-Level Wastes by Shallow Land Burial and Alternative Disposal Methods (Proposed)
10 CFR 71	-	Packaging of Radioactive Material for Transport and Transportation of Radioactive Material Under Certain Conditions
10 CFR 150	-	Exemptions and Continued Regulatory Authority in Agreement States

exposure standards for employees working with the material (e.g., 10 CFR 20.101 gives radiation dose standards for individuals in restricted areas) as well as radiation exposure standards affecting the general population (e.g., 10 CFR 20.105 states the permissible levels of radiation in unrestricted areas). Also, procedures are prescribed for reporting accidents (e.g., 10 CFR 20.402 states the procedure for reporting theft or loss of material).

Concerning radiation standards for waste disposal of DU, Part 20 states that no licensed material can be buried in soil unless:

- The total quantity of licensed material at any one location and time does not exceed specified amounts
- Burial is at a minimum depth of 4 feet
- Successive burials are separated by distances of at least 6 feet, and not more than 12 burials are made in any calendar year.

The Nuclear Regulatory Commission's licensing authority is its most effective tool in regulating radioactive material. In 10 CFR 40, the requirements for a source material license are given. Terms of the license include procedures for recording the receipt, transfer, and disposal of source material; for inspecting the material and the facilities where material is used or stored; and for enforcing any violation of the license conditions.

Two types of licenses are permitted: general and specific. The general license is effective without filing applications with the Commission or issuance of licensing documents to particular persons. It is issued to commercial and industrial firms and public agencies if no more than 15 pounds of the material is used or transferred by the organization at any one time and no more than 150 pounds is received in any one calendar year. A specific license is necessary if commercial or government organizations wish to receive, possess, use, or transfer source material but do not qualify for a general license. An application must be filed with, and the license granted by, the Nuclear Regulatory Commission.

The National Environmental Policy Act of 1969 (NEPA) requires all agencies of the Government to prepare detailed environmental statements on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment. Part 51 of Title 10 sets forth NRC policies and procedures for preparing and processing environmental impact statements (EIS). An EIS is specifically required before a license can be issued that authorizes land burial of DU.

Part 61 deals with a specific regulatory program for the management of low-level radioactive waste. This part of Title 10 is still in the rulemaking stage. When finalized, Part 61 will identify specific issues to be addressed within an EIS, set explicit standards for the disposal of low-level wastes, and develop

criteria for waste performance (e.g., site suitability, design, monitoring, and decommissioning).

In 10 CFR 71, NRC regulations for shipping and packaging radioactive material are given; these supplement the Department of Transportation's (DOT's) requirements for transporting hazardous materials (Subsection A,2). In particular, Part 71 extends the scope of DOT's hazardous materials regulations to cover intrastate commerce as well as the transport of radioactive material by air other than in civil aircraft, and prescribes standards for the handling of licensed materials on-site.

Finally, Part 150 specifies certain conditions under which individual states are allowed to establish regulatory programs for source material. The authority of these Agreement States is discussed in Subsection A,5.

2. DEPARTMENT OF TRANSPORTATION

Under the Department of Transportation Act of 1966 and the Hazardous Material Act of 1974, DOT was given regulatory responsibility for the safe transportation of radioactive materials by all modes of transport in interstate or foreign commerce (rail, road, air, water) and by all means (truck, bus, automobile, ocean vessel, airplane, river barge, railcar, etc.) except postal shipments. Postal shipments come under the jurisdiction of the U.S. Postal Service (Subsection A,4). Shipments not in interstate nor foreign commerce are subject to control by NRC and state agencies.

Areas in which DOT has enacted standards include material form and packaging, package labeling and marketing, permissible dose level during transport, contamination control, carrier licensing and shipper certification, and incident reporting. These regulations are found in Title 49 of the Code of Federal Regulations (CFR), Parts 171-178, 392, and 394 (Table A-2) (Reference A-2). Appendix C in the Army Handbook of Safety Procedures for

TABLE A-2. CURRENT REGULATIONS OF THE DOT
TITLE 49 - CODE OF FEDERAL REGULATION

49 CFR 171	-	Central Information, Regulations, and Definitions
49 CFR 172	-	Hazardous Materials Table and Hazardous Materials Communications Regulations
49 CFR 173	-	Shippers -- General Requirements for Shipments and Packagings
49 CFR 174	-	Carriage by Rail
49 CFR 175	-	Carriage by Aircraft
49 CFR 176	-	Carriage by Vessel
49 CFR 177	-	Carriage by Public Highway
49 CFR 178	-	Shipping Container Specifications
49 CFR 392	-	Driving of Motor Vehicles
49 CFR 394	-	Notification, Reporting, and Recording of Accidents

Processing Depleted Uranium gives an overview of DOT regulations applicable to the transportation of DU (Reference A-3).

The primary consideration for safe transportation of DU is the use of proper packaging for the particular form of DU to be transported. According to the regulations stated in 49 CFR 173.398 and 49 CFR 173.389, the particular form as applied to DU can be labeled either "special" or "normal." All DU metal components or scrap are considered "special form." This material, if released, may present an external radiation hazard, but little danger due to radiotoxicity. Any DU which does not qualify as special form is classified "normal form" (i.e., DU chips, turnings, and swarf).

The Department of Transportation also has two types of packaging schemes for radioactive materials called Type A and

Type B. Type A packaging must be designed according to general packaging requirements as prescribed in 49 CFR 173.393 and must be adequate to prevent loss or dispersal of the radioactive contents and to maintain its radiation shielding properties if the package is subject to the defined "normal" conditions of transport. Type A packaging may be a fiberboard box, wooden box, or steel drum that meets DOT specifications. Table A-3 gives a brief summary of the general packaging and shipping requirements for radioactive materials that are found in Part 173.393. Type B packaging applies to high-level radioactive materials and is not required for DU.

3. DEPARTMENT OF DEFENSE

The military is a prime generator and manager of low-level radioactive waste in general and DU in particular. Depleted uranium metal and its alloys have found application in various areas of military operations, e.g., in aircraft and missile counterweights, radiation shielding, ammunition, weapons, gyrorotors, and ballast.

The Department of Defense (DoD) regulations concerning low-level radioactive waste consist of DOT and NRC regulations plus international DoD rules and procedures. The licensing of DU material, material handling requirements, and disposal at commercial facilities are governed by NRC. The transportation of DU outside DoD facilities and across state boundaries is regulated by DOT. However, DoD has responsibility for managing the waste which is generated at its own facilities (Reference A-4).

Table A-4 is a listing of regulations and documents that have been issued by DoD and the Department of the Air Force. Most of these documents serve the purpose of alerting personnel to government regulations which must be met. References to or reiteration of other federal agency regulations are given where applicable. Internal rules and procedures that must be followed are designated.

TABLE A-3. GENERAL PACKAGING AND SHIPMENT REQUIREMENTS[a]

a) The outside of each package must incorporate a feature such as a seal, which is not readily breakable and which, while intact, will be evidence that the package has not been illicitly opened.

b) The smallest outside dimension of any package must be 4 inches or greater.

c) Each radioactive material must be packaged in a packaging which has been designed to maintain shielding efficiency and leak tightness, so that, under conditions normally incident to transportation, there will be no release of radioactive material. Each package must be capable of meeting the standards in 49 CFR 173.398(b) and 173.34.

d) The packaging must be designed, constructed, and loaded so that during transport:

(1) The heat generated within the package because of radioactive materials present will not, at any time during transportation, affect the efficiency of the package under the conditions normally incident to transportation, and

(2) The temperature of the accessible external surfaces of the package will not exceed 122°F in the shade when fully loaded, assuming still air at ambient temperature. If the package is transported in a transport vehicle consigned for the sole use of the consignor, the maximum accessible external surface temperature shall be 180°F.

e) Pyrophoric materials must also meet the packaging requirements of 49 CFR 173.134 and 173.154

f) Liquid radioactive material in Type A quantities must be packaged in or within a leak-resistant and corrosion-resistant inner containment vessel. In addition:

(1) The packaging must be adequate to prevent loss or dispersal of the radioactive contents from the inner containment vessel if the package were subject to a 9 meter drop test.

(2) Enough absorbent material must be provided to absorb at least twice the volume of radioactive liquid contents.

g) There must be no significant removable radioactive surface contamination on the exterior of the package.

h) Except for shipments described in paragraph (i), all radioactive materials must be packaged in suitable packaging so that at any time during normal conditions incident to transportation, the radiation dose rate does not exceed 200 millirem per hour at any point on the exterior of the package.

i) Packages for which the radiation dose rate exceeds the limits specified in paragraph (h), but does not exceed at any time during transportation any of the limits specified in paragraphs (i)(1) - (i)(4) may be transported in a transport vehicle which has been consigned as exclusive use (except aircraft). Specific instructions for maintenance of the exclusive use (sole use) shipment controls must be provided by the shipper to the carrier. Such instructions must be included with the shipping paper information:

(1) 1,000 millirem per hour at 3 feet from the external surface of the package (closed transport vehicles only).

(2) 200 millirem per hour at any point on the external surface of the car or vehicle (closed transport vehicle only).

[a]Under particular circumstances, special regulations, which have not been detailed, may need to be followed in transporting DU.

Source: 49 CFR 173.393 (Reference A-2).

TABLE A-3. GENERAL PACKAGING AND SHIPMENT REQUIREMENTS[a] (Concluded)

(3) 10 millirem per hour at any point 2 meters from the vertical planes projected by the outer lateral surface of the car or vehicle; or if the load is transported in an open transport vehicle, at any point 2 meters from the vertical planes projected from the outer edges of the vehicle.

(4) 2 millirem per hour in any normally occupied position in the car or vehicle, except that this provision does not apply to private motor carriers.

j) Packages consigned for export are also subject to the regulations of foreign governments.

k) Prior to the first shipment of any package, the shipper shall determine that:

(1) The packaging meets the specified quality of design and construction.

(2) The effectiveness of the shielding and containment and, where necessary, the heat transfer characteristics of the package are within the limits applicable to or specified for the package design.

l) Prior to each shipment of any package, the shipper shall insure that:

(1) The package is proper for the contents shipped.

(2) The packaging is in unimpaired physical condition except for superficial marks.

(3) Each closure device of the packaging is present in proper condition.

(4) All special instructions have been followed.

(5) Each closure, valve, and any other opening of the containment system through which the radioactive content might escape is properly closed and sealed.

(6) If the maximum normal operating pressure of a package is likely to exceed 0.35 kilogram per square centimeter (gage), the internal pressure of the containment system will not exceed the design pressure during transportation.

(7) External radiation and contamination levels are within the allowable limits.

m) No person may offer for transportation a package of radioactive materials until the temperature of the packaging system has reached equilibrium unless, for the specific contents, he has ascertained that the maximum applicable surface temperature limits cannot be exceeded.

n) No person may offer for transportation aboard a passenger carrying aircraft any radioactive material unless that material is intended for use in, or incident to, research, medical diagnosis or treatment, or is excepted under the 49 CFR 175.10

[a]Under particular circumstances, special regulations, which have not been detailed, may need to be followed in transporting DU.

Source: 49 CFR 173.393 (Reference A-2).

TABLE A-4. DIRECTIVES CONCERNING RADIOACTIVE MATERIALS

Department of Defense	
Item DI-H-1332	- Radioactive Material Data
DoD Directive 5100.52	- Radiological Assistance Responsibilities in Event of an Accident Involving Radioactive Material
DoD Directive 4140.34-M	- Defense Utilization Manual
DoD Directive 4160.21-M	- Defense Disposal Manual (Restructured)
Dod Directive 4500.32-R	- Volume 1, Military Standard of Transportation and Movement Procedures
Military Specifications/Standards	
MIL-STD-105	- Sampling Procedures and Tables for Inspection by Attributes
MIL-STD-129F	- Marking For Shipment and Storage
MIL-STD-450B	- Signs for Contaminated or Dangerous Area
MIL-STD-1320A	- Truck Loading of Hazardous Material
MIL-STD-1325A	- Rail Car Loading of Hazardous Material
MIL-STD-1458	- Radioactive Materials; Marking and Labeling of Items, Packages and Shipping Containers for Identification in Use, Storage and Transportation
MIL-M-19590	- Marking of Commodities and Containers to Indicate Radio. 'ive Material
MIL-C 82240B	- Cover, Footwear, Radioactive Contaminant Protection
MIL-G 82241B	- Gloves, Inserts Radioactive Contamination
MIL-G 82242B,	- Gloves, Radioactive Contaminant Protection
MIL-C 82243B(1)	- Coveralls, Radioactive Contaminant Protection
MIL-H 82244B(1)	- Hood, Radioactive Contaminant Protection
MIL-O 82246C	- Overshoes, Radioactive Contaminant Protection
Department of the Air Force	
AFR 78-18	- Computation & Reporting of Requirements for Depleted Uranium
AFR 160-124	- Radioisotope License and Permits
AFR 71-4	- Preparation of Hazardous Materials for Military Air Shipment
AFR 75-18	- Reporting of Transportation Discrepancies in Shipments
AFR 136-4	- Responsibilities for Technical Escort of Dangerous Materials
AFR 161-8	- Control and Recording Procedures - Occupational Exposure to Ionizing Radiation
AFR 161-17	- Environmental Health, Forensic Toxicology, and Radiological Health Professional Support Functions
AFR 161-28	- Personnel Dosimetry Program and the USAF Master Radiation Exposure Registry
AFR 160-132	- Control of Radiological Health Hazards
AFM 67-8	- Radioactive Commodities in the DoD Supply Systems
AFM 71-4	- Packaging and Handling of Dangerous Materials for Transportation on Military Aircraft
AFM 127-2	- USAF Accident/Incident Reporting
AFM 160-30	- Radiologic Technology
AFP 160-6-7	- Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure

Source: Reference A-3

4. OTHER FEDERAL AGENCIES

Several other government agencies have minor authority for the managment of DU material. Most of their activities are in areas such as equipment certification, inspection procedures, and worker health and safety programs. The Agencies which have a role in transportation and disposal of DU are:

- Environmental Protection Agency (EPA) - This Federal agency is empowered to protect and regulate the environment. By its authority to set generally applicable environmental standards (from such legislation as the Clean Air Act and the Federal Water Quality Control Act), the EPA has set standards for maximum levels of radiation levels in air and in public waters. Under the Resource Conservation and Recovery Act of 1976, the agency is given control over the disposal of waste containing naturally-occurring and accelerator-produced materials. Examples of such waste are radium sources, phosphate mining and processing residues, and certain high-radium zirconium mining and milling residues. Also, EPA controls the disposal of all waste in the oceans under the Marine Protection, Research, and Sanctuaries Act of 1972.

- National Bureau of Standards (NBS) - Part of the Department of Commerce that is responsible for the custody, maintenance, and development of national standards of measurement and the development and application of measurement technologies upon which the flow of interstate and foreign commerce must necessarily depend. Pertaining to DU, NBS has handbooks on such topics as radiological monitoring methods and instruments (NBS No. 51), maximum permissible body burdens and maximum permissible concentrations of radionuclides in air and in water for occupational exposure (NBS No. 84), and radiation quantities and units (NBS No. 84).

- Occupational Safety and Health Administration (OSHA) - OSHA was formed within the Department of Labor as a result of the Occupational Safety and Health Act of 1970. Its primary function is to enact and enforce occupational health

and safety standards (including radiation exposure) in the private sector. Although OSHA has no enforcement power within Federal agencies, it is supposed to work with the head of each agency to establish and maintain an effective and comprehensive program which is consistent with the standards promulgated under the Act. Title 29, Part 1910 of the Code of Federal Regulations lists the occupational safety and health standards.

- U.S. Postal Service - Quantities of DU exempt from DOT regulations (i.e., emitting less than 1 millicurie) can be shipped by U.S. mail provided that certain conditions are fulfilled. These conditions are stated in U.S. Postal Service Publication No. 6, Radioactive Matter.

5. AGREEMENT STATES

Section 274 of the Atomic Energy Act of 1954 as amended permits transfer of certain regulatory authority over radioactive source material to any state when:

- A State desires to assume this authority
- The Governor certifies that the State has an adequate regulatory program
- The NRC finds that the State's program is compatible with that of NRC and is adequate to protect the public health and safety.

Currently there are 25 Agreement States, including Florida. (All three commercial low-level waste disposal sites -- Barnwell, SC, Beatty, NV, and Richland, WA -- are located in Agreement States.) The agreements allow the States to take over licensing and regulatory responsibilities for source materials. Included in the states' responsibilities are regulations concerning: permissible dose levels and concentrations; record keeping, reporting, and accident notification; licensing of radioactive material; intrastate transportation; and waste disposal (Reference A-5).

In addition to specifying State licensing and regulatory responsibility, each agreement made recognizes the importance of maintaining compatible programs and of providing for reciprocal recognition of licenses. The agreements contain an article pledging the use of best efforts by NRC and the States to achieve coordinated and compatible programs (Reference A-6).

6. REGULATION OF URANIUM MILL TAILINGS

Uranium tailing piles are classified by NRC as by-product material, and thus are subject to NRC's licensing regulations (10 CFR Parts 30-35). In addition, the passage of the Uranium Mill Tailings Radiation Control Act of 1978 (UMTCA) increased NRC's regulatory authority relating to active mill operations and tailings generation, provided for long-term control of tailings, and authorized remedial actions at inactive mill tailings sites (Reference A-7).

The Uranium Mill Tailings Radiation Control Act enables NRC to subject tailings piles to more extensive requirements than other by-product materials. Also, it authorizes the NRC to take appropriate measures to protect public health and safety and the environment from radiological hazards associated with such material.

Under Section 206 of UMTCA, a new section (275) is added to the Atomic Energy Act which grants EPA the power to establish standards of "general application" covering radiological and non-radiological hazards from mill tailings located at active mill sites. NRC is responsible for enforcement of these standards. EPA also has the responsibility to establish general standards for inactive sites and to develop guidelines for remedial actions (Reference A-6).

The Department of Energy (DOE) has a major role in the long-term control of uranium mill tailings disposal sites. The

Uranium Mill Tailings Radiation Control Act specifies that DOE shall assume custody of inactive sites that are government-owned. However, NRC, through its licensing powers, can require DOE to perform certain monitoring or maintenance duties or to undertake particular emergency measures to protect public health and safety (Reference A-7, Section 202a).

Agreement States have been given considerable authority under UMTCA. Five Agreement States are currently licensing uranium milling activities within their borders; these are Arizona, Colorado, New Mexico, Texas, and Washington. The Uranium Mill Tailings Radiation Control Act requires the Agreement States to regulate tailings in accordance with standards that are, to the extent practicable, equivalent to or more stringent than standards set by NRC and EPA (Reference A-7, Section 204). This requirement represents a slight departure from existing agreements with the states which specify that state programs be "compatible" with those of NRC. As part of a program to strengthen health and safety regulation of uranium mills, NRC is offering technical assistance to Agreement States in assessing the environmental impact considerations required for licensing uranium mills.

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A-4. "Regulation of Federal Radioactive Waste Activities," Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, NUREG-0527, September 1979.

A-5. "Control of Radiation Hazard Regulations," Department of Health and Rehabilitative Services, State of Florida, revised January 1, 1977.

A-6. "Draft Generic Environmental Impact Statement of Uranium Milling," Volumes I and II, U.S. Nuclear Regulatory Commission, NUREG-0511, April 1979.

A-7. The Uranium Mill Tailings Radiation Control Act of 1978, Pub. 2, No. 95-604, 92 Stat. 3021, 1978.

APPENDIX B
INFORMATION SOURCES

Manufacturing Industry

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Harvey Drucker
Aerojet
Downey, CA
(213) 923-7511

Bill Neff
E-Cubed, Inc.
Denville, NJ
(201) 625-2600

DOE/GOCO Facility

L.M. Levy
National Lead Company of Ohio
(Feed Materials Production Center)
(513) 738-1151

R.J. Jackson
Energy Systems Group
Rocky Flats Plant
Golden, CO
(303) 497-2181

Merwyn Sanders
Union Carbide Corporation
(Y-12 Plant)
Oak Ridge, TN
(615) 574-3545

Decommissioned Missile Silos

MAJ Clark
SAC Headquarters
Offutt AFB, NB
(402) 294-6236

Fuel Reprocessing Plant

Department of Energy
Defense Programs
Washington, DC
(202) 252-5800

Idaho Operations Office, ID
(208) 522-6640

Savannah River Operations Office, SC
(803) 824-6331

Richland Operations Office, WA
(509) 376-7200

Uranium Mill

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Phosphate Tailings

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DOE Disposal Site

Jim Dieckhoner
Department of Energy
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APPENDIX C

ANNOTATED BIBLIOGRAPHY

Depleted Uranium Processing

"Safety Procedures for Processing Depleted Uranium," U.S. Army Materiel Development and Readiness Command, DARCOM HDBK 385-1.1-78, August 1978.

This handbook describes the various aspects of handling depleted uranium including manufacturing, health and safety, transportation, and pertinent regulations. All phases of the manufacturing process for depleted uranium in munitions are detailed. Safety requirements and procedures for personnel training, decontamination practices, radiation monitoring, air quality sampling, etc. are outlined for each stage in the production process. In addition, all regulations and standards applicable to the handling and processing of depleted uranium material are identified.

Cadden, J.L., "Melting and Casting of Uranium Alloys," Proceeding of the Third Army Materials Technology Conference, Physical Metallurgy of Uranium Conference, (J.J. Burke, et al., editors), Brookhill Publishing Company, Chestnut Hill, Massachusetts, 1976.

This chapter provides a detailed discussion on uranium alloy melting. The authors describe six techniques used in research and industry; these include vacuum induction, vacuum arc, vacuum skull, electroslag, inductoslag, and plasma arc melting. For each method emphasis is placed on melting parameters, impurities, and alloy segregation. In addition, diagrams are given of the equipment in use at the Y-12 Plant and National Lead of Ohio.

Olofson, C.T., et al., "Processing and Application of Depleted Uranium Alloy Products," Metals and Ceramics Information Center, MCIC-76-28, September 1976.

This report gives a detailed description of the metallurgy and applications of depleted uranium. The discussion begins with the processing of green salt (UF_4) to produce pure uranium metal. The next section characterizes the properties of uranium alloys.

Of particular interest is the discussion on the melting techniques which are used to produce and recycle depleted uranium alloys. The methods that are covered are induction melting, arc melting, skull casting, electroslag refining, and inductoslag melting. The last section of this document covers the current and future uses of depleted uranium; these include aircraft control counterweights, radiation shielding, and armor-piercing penetrators.

Uranium Mill and Mill Tailings

Schneider, K.J. and Kabele, T.J., "Descriptions of Reference LWR Facilities for Analysis of Nuclear Fuel Cycles," Pacific Northwest Laboratory, PNL-2286/UC-11, September 1979.

This document was written to provide the Department of Energy with a characterization of the nuclear fuel cycle. All of the major steps of the uranium fuel cycle are discussed: mining, milling, purification and coversion, enrichment, fuel fabrication, and reprocessing. For each phase, typical plant facilities, engineering processes, and airborne and liquid effluents to the environment are described. In addition, a chapter is devoted to the boiling water reactor and pressurized waste reactor.

"Draft Generic Environmental Impact Statement on Uranium Milling," Volumes I and II, U.S. Nuclear Regulatory Commission, NUREG-0511, April 1979.

This document was prepared to assess the environmental impact of the uranium milling industry in the U.S. on both a short-term and long-term basis. In addition, it recommends new standards for the operation and decommission of uranium mills and tailings. The following areas are discussed in detail: history and problems of the milling industry, characterization of a model uranium mill, environmental impacts (best and worst situations), health effects, potential accidents, and management and monetary alternatives for future mill operations. In conclusion, it evaluates the needs for financial surety for tailings disposal and discusses the unavoidable impacts from the U.S. milling industry to the year 2000.

Eichholz, G.G., Environmental Aspects of Nuclear Power, Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan, 1977.

The author covers a range of issues regarding the U.S. nuclear industry and its effects on the environment. The text provides a solid foundation in the following areas: the fuel cycle industries, the transportation of nuclear fuels, the siting of power plants, the types of nuclear plants, the dispersion of radioactive effluents to the environment, the disposal options for radioactive wastes, and the social and economic assessments necessary in evaluating the nuclear power question.

Yemel'Yanov, V.S. and Yevstyukhin, A.I., (translated by A. Foster), The Metallurgy of Nuclear Fuel, Pergamon Press, New York, 1969.

The authors have divided this text into three parts, corresponding to the fissionable components of nuclear fuel, i.e., uranium, thorium, and plutonium. The physical, chemical, and mechanical properties of these elements are discussed. The areas of detailed study are mineralogy, concentrating and purifying techniques, methods of producing pure metals, effects of radiation, characteristics of alloys, and production of compounds. Of particular interest is the chapter regarding the uranium mill; included is a discussion of the grinding and crushing of ores, the leaching by acid or carbonate processes, and the separating by absorption or solvent extraction techniques.

Harrington, C.D. and Ruehle, A.E., Uranium Production Technology, D. Van Nostrant Company, Inc., Princeton, New Jersey, 1959.

The author has written this book under the guidance of the Atomic Energy Commission with the purpose of describing the technology used in the production of uranium and its compounds. The text described the chemistry in generating uranium metal, uranium dioxide, uranium trioxide, uranium tetrafluoride, uranium hexafluoride, and enriched uranium. In particular, a chapter is devoted to the solvent extraction technique using TBP (tributyl phosphate); variations of this method are used at the milling and reprocessing plants. In addition, the metalworking processes are discussed; these include casting, press forging, extruding, rolling, and swaging.

Clegg, J.W. and Foley, D.D., (Editors), Uranium Ore Processing, Addison-Wesley Publishing Company, Inc., 1958.

The first four chapters of the text provide an introduction to the geology, mineralogy, mining, and sampling

and analysis of uranium ores. These are followed by a detailed discussion of the uranium milling process. This includes ore preparation, acid leaching, carbonate leaching, liquid-solid separation, ion exchange, and solvent extraction. The text concludes with examples of milling operations and a discussion of the health and safety issues involved in uranium ore processing.

Fuel Reprocessing

Bebbington, W.P., "The Reprocessing of Nuclear Fuels," Scientific American, Vol. 235, No. 6, December 1976, pp. 30-44.

This article provides an historical and engineering introduction to the reprocessing of spent nuclear fuel. It describes diagrams of an extraction column, mixer-settler and centrifugal contractor which are the major hardware components in the reprocessing phase. Also, there is a discussion on the Purex process which is used to extract uranium and plutonium. Integrated throughout this article are the histories and capabilities of U.S. reprocessing facilities.

Long, J.T., Engineering for Nuclear Fuel Reprocessing, American Nuclear Society, LaGrange Park, Illinois, 1968.

The purpose of this book is to provide a comprehensive review of the chemical engineering technology used in processing of spent nuclear fuel. It addresses the following topics: separation methods, spent fuel dissolution, heat transfer and mechanical operations, solvent extraction, plant design and operation, and economical factors in reprocessing. Where applicable the chemical limitations of these processes are discussed.

Glasstone, S. and Sesonske, A., Nuclear Reactor Engineering, D. Van Nostrand Company, Inc., Princeton, New Jersey, 1967.

The authors have provided the classic introductory text on the fundamentals of nuclear reactor engineering. Of particular interest is the section on the reprocessing of spent nuclear fuel in which three separation techniques that can be used are described. These are volatilite, pyrometallurgical, and solvent extraction methods. The text begins with a discussion on nuclear reactions and radioactive materials. This is followed by the principles

of neutron diffusion and reactor theory. The majority of the text describes the components of the nuclear reactor design, moderator and shielding materials, nuclear fuel cycle, energy removal, and radiation protection. The last chapter discusses the economics of the nuclear industry.

Benedict, M. and Pigford, T.H., Nuclear Chemical Engineering, McGraw-Hill Book Company, Inc., New York, 1957.

The authors give a detailed study of the chemical engineering processes in the nuclear fuel industry. The text begins with an overview of nuclear physics and radiochemistry. This is followed by a discussion of the nuclear reactions in a thermal reactor. Next there is a description of uranium, zirconium, thorium, and beryllium and their various uses. In addition a chapter is devoted to the properties of irradiated fuel. Finally a detailed discussion of the standard chemical processes of nuclear engineering is given. This includes solvent extraction, isotope enrichment, and isotope separation.

Schneider, K.J. and Kabele, T.J., "Descriptions of Reference LWR Facilities for Analysis of Nuclear Fuel Cycles" (See Uranium Mill & Mill Tailings).

Eichholz, G.G., Environmental Aspects of Nuclear Power (See Uranium Mill & Mill Tailings).

Harrington, C.D. and Ruehle, A.E., Uranium Production Technology (See Uranium Mill & Mill Tailings).

Phosphate Tailings

Sine, C., "Phosphate: Report from Bone Valley," Farm Chemicals, Vol. 143, No. 2, February 1980, pp. 13-31.

This article provides an overview to the phosphate industry in Florida. By using many photographs, a short glossary, and diagrams, the author describes the mining and milling processes that take place at Bone Valley east of Tampa. Included in this discussion are the costs for two large mines, the future growth of the industry, and an outline of the regulatory system associated with this industry. In

addition, the article provides a list of current and proposed phosphate operations in Florida. A brief discussion of extracting uranium from phosphoric acid is also given.

Horton, T.R., "A Preliminary Radiological Assessment of Radon Exhalation From Phosphate Gypsum Piles and Inactive Uranium Mill Tailings Piles," U.S. Environmental Protection Agency, EPA-520/5-79-004, September 1979.

This brief document deals with the radiological impact of radon gas generated from radium, which is found in phosphate gypsum waste piles and inactive uranium mill tailings piles. From measured exhalation rates, indoor concentrations, individual exposures and population exposures are calculated. A final summary indicates that maximum individual exposure is less from the gypsum pile; on the other hand, the population exposure is higher for the gypsum pile in Florida than the uranium mill tailings in the southwestern U.S.

Guimond, R.J. and Windham, S.T., "Radioactivity Distribution in Phosphate Products, By-Products, Effluents, and Wastes," U.S. Environmental Protection Agency, ORP/CSD-75-3, August 1975.

This report provides a discussion on the radioactive sources associated with the mining and milling of phosphate ores. Starting from the beneficiation process, the isotopes of uranium thorium, and radium are analyzed for their activity among the wastes and products. Next a brief description of the wet process, which is used to produce phosphoric acid, is given. Included in this discussion are the measurements of activity from these isotopes and the effects of liming in reducing their distribution in the effluents. Similarly, the thermal process, which is used to produce elemental phosphorous, is also described. Finally, a section is devoted to the potential resource of uranium in the phosphate ores.

Low-Level Waste Disposal Sites

Murphy, E.S. and Holter, G.M., "Technology, Safety and Costs of Decommissioning a Reference Low-Level Waste Burial Ground," Volumes I and II, Pacific Northwest Laboratory, NUREG/CR-0570, June 1980.

These documents have been prepared for the U.S. Nuclear Regulatory Commission to assist them in developing regulations relative to the decommissioning of low-level radioactive waste burial grounds. In this study, two generic commercial sites are described and analyzed. One is located in an arid western state and the other in a humid eastern state. Decommissioning options are reviewed, which include waste stabilization, long-term maintenance, and waste relocation. In addition, economic factors, environmental considerations, and public safety are discussed.

"Facts About Low-Level Radioactive Waste," for State Planning Council Briefing, U.S. Department of Energy, February 1980.

This document provides an overview on the subject of low-level waste (LLW) in the U.S. It begins with some statements made by the governors where LLW is commercially buried and testimony by the Secretary of Energy regarding DOE's role in the disposal problem. Following these comments there are two chapters on commercial LLW disposal sites. Included in these sections are tables and slides of site characteristics, i.e., location, size, amount of buried waste, area left for LLW, types of LLW, and generators of LLW. Next there is a similar discussion of DOE's facilities and disposal sites. Finally two short sections of this document are devoted to the transportation and economics of commercial LLW.

"Nuclear Waste Management Program Summary Document FY 80," U.S. Department of Energy, DOE/ET-0094, April 1979.

This document reviews the present and future operation of the Office of Nuclear Waste Management. It begins with a description of the U.S. energy policy indicating how Congressional legislation has affected DOE. Next, there is a management overview discussing strategy, budget, and structure. A large portion of this document is devoted to the sub-activities of this office. Of particular interest are the discussions regarding National Laboratories and the long-term disposing of high- and low-level radioactive wastes.

Seabed Disposal

"Subseabed Disposal Program Plan Volume I: Overview," Sandia Laboratories, SAND80-0007/1, January 1980.

This document outlines DOE's plan for evaluating the technical and environmental feasibility of subseabed disposal and the engineering development and operation of such a facility. Provided in this overview is a time table for meeting these goals by the end of this century. In addition, the technical components of the Subseabed Disposal Program are described. This includes site studies for ranking various areas, environmental studies for researching physical and biological properties, emplacement methods such as trench or drill, transportation from land to sea, and finally social-scientific issues from an international and legal point of view.

Deese, D.A., Nuclear Power and Radioactive Waste, D.C. Heath and Company, Lexington, Massachusetts, 1978.

This text provides a study into the option of subseabed disposal of radioactive waste. An overview is given of past marine disposal practices and current worldwide waste management programs. The legislative and regulatory positions of the U.S. and other nations are discussed. International laws regarding subseabed disposal are reviewed in the context of establishing a worldwide agreement. In addition, the political and ethical questions affecting this option are discussed.

Regulatory Considerations

"Title 49, Chapter 1, Code of Federal Regulations-Transportation," Office of the Federal Register, National Archives and Records Service, U.S. General Services Administration, revised October 1, 1979.

Title 49, Chapter 1 has the rules and regulations for the Research and Special Programs Administration of the Department of Transportation. DOT standards that pertain to the transportation of hazardous materials are found in this chapter. Those parts which are relevant to DU disposal are: Part 171, Regulations and Definitions Concerning Hazardous Materials; Part 172, Hazardous Materials Table; Part 173, General Requirement for Shipments and Packages; Part 174, Carriage by Rail; Part 175, Carriage by Aircraft; Part 176, Carriage by Vessel; Part 177, Carriage by Public Highway; Part 178, Shipping Container Specifications; Part 392, Driving of Motor Vehicles; and Part 394, Notification, Reporting and Recording of Accidents.

"Regulation of Federal Radioactive Waste Activities," Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, NUREG-0527, September 1979.

This document is the summary of a study undertaken by the NRC, at the direction of Congress, to assess the possible extension of the Commission's licensing and regulatory authority to include categories of existing and future Federal radioactive waste storage and disposal activities not presently subject to such authority. A major portion of the study is devoted to a complete listing and inventory, by waste category, of all Federal radioactive waste storage and disposal activities. Also, the study has attempted to present a general comparison of the relative potential hazards associated with defense-generated and commercial wastes, taking into account alternative disposal methods.

"Title 10, Chapter 1, Code of Federal Regulations - Energy," Office of the Federal Register, National Archives and Records Services, U.S. General Services Administration, revised October 1, 1979.

Title 10, Chapter 1 has the rules and regulations that have been enacted by the Nuclear Regulatory Commission. Those parts that particularly apply to the waste management of DU are: Part 20, Standards for Protection Against Radiation; Part 40, Domestic Licensing of Source (DU) Material; Part 51, Licensing and Regulatory Policy and Procedures for Environmental Protection; Part 61, Management and Disposal of Low-Level Wastes; Part 71, Packaging of Radioactive Material for Transport; and Part 150, Exemptions and Continued Authority in Agreement States.

"Technical Order 00-110N-2 - Radioactive Waste Disposal," Department of the Air Force, U.S. Department of Defense, November 15, 1979.

This technical order provides instructions for handling, packaging, and disposing of unclassified radioactive material and outlines the precautions to be observed.

"Air Force Regulation 160-132 - Control of Radiological Health Hazards," Department of the Air Force, U.S. Department of Defense, December 5, 1968.

This regulation establishes the USAF Radiological Health Program, and prescribes policies and areas of responsibility concerned with the protection of Air Force personnel from the effects of ionizing radiation during routine,

non-emergency conditions. Included are standards for contamination levels and controls, monitoring, handling of material in Government laboratories, protective clothing, and maximum permissible exposure levels.

"Control of Radiation Hazard Regulations," Department of Health and Rehabilitative Services, State of Florida, revised January 1, 1977.

This document details the regulations for both the control of radiation hazards and the transportation of radioactive materials for the State of Florida. Included here are the Florida regulations that pertain to DU material which is subject to the provisions of an agreement between the State and the U.S. Nuclear Regulatory Commission.

The Uranium Mill Tailings Radiation Control Act of 1978, Pub. 2, No. 95-604, 92 Stat. 3021, 1978.

The uranium milling industry and the mill tailings waste disposal problems are issues of national importance, involving very long-term and potentially widespread environmental impacts. Past management of uranium mill tailings has been poor. Misuse of the tailings has included construction with tailings material and removal of the tailings to offsite locations. The Uranium Mill Tailings Radiation Control Act authorizes remedial actions at inactive mill tailings sites, strengthens regulatory authorities relating to active mill operations and tailings generation, and provides for long-term control of tailings.

"Safety Procedures for Processing Uranium" (see Depleted Uranium Processing).

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